# PERCEPTION OF TANGIBLE GRAPHIC DISPLAYS BY BLIND PERSONS

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# Perception of Tangible Graphic Displays by Blind Persons[1]

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[1] Presented at the annual meeting of the American Psychological Association, Montreal, Canada, September, 1980.

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# Haptic Perception of Tangible Graph Displays

## Problem: The Haptic Reading of Tangible Graphic Displays

The reading of tangible graphic display is dependent upon three factors, namely, the legibility of the symbology contained in the display, the tactual-motor skills necessary for exploring and reading the display, and the knowledge the reader brings to the task at hand (Nolan ad Morris, 1971). While research on each of these factors has generated a small body of knowledge, there has generally been only slight improvement in the quality of tangible graphic displays and very little accomplished by way of improving the skills and concept development of blind children who are supposed to use graphic displays in a variety of subject areas. The crux of the problem is the fact that the producers of tangible graphic displays have little knowledge of tactual perception or the problems facing blind children. Consequently, the graphic displays which appear in braille books are generally reported to be difficult for blind childen to read (Nolan and Morris, 1971; Berla', 1975). Because the graphics are poorly disigned many teachers avoid using them to any extent in the classroom. Blind children, as a result, are not given the opportunity to

use them and not only fail to develop rudimentary skills for reading them, but also are not given the opportunity to acquire the information which is conveyed through these displays. For example, a common complaint of social studies teachers in the higher grade levels of residential schools for the blind is that children in the classes lack even the simplist of skills for reading maps. Consequently, when they attempt to introduce a tangible map as part of a lesson they are faced with the dilemma of either avoiding the use of maps altogether or teaching the basic skills which would then take a considerable amount of time away from the teaching of other subjects. Although attempts have been made in recent years to improve the quality of tangible maps (Nolan and Morris, 1971) and to delineate the concepts and skills necessary for reading maps (Berla, 1975; Franks, 1974) very little of this information has been incorporated either into commercially produced tangible maps or into the curricula for blind children. The consequence of this state of affairs is that tangible maps and other graphics are of poor quality and blind children lack the skills and knowledge necessary for reading them. Researchers who then attempt to test different map designs are basically faced with a population of subjects who lack the skills necessary to read them and this makes research on graphic design and legibility very difficult.

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## Legibility of Graphic Displays

### Size

The size of tactual displays and the size of the symbols on them are of major importance in designing readable graphics. Since the resolving power of the fingertip is much less than that of the eye, it is often necessary to enlarge the symbols and the size of the display for the haptic reader. For example, a typical map in an inkprint text would need to be enlarged several times in order to provide the haptic reader with the same information that is available to the sighted reader. However, as the size of the haptic display is increased it creates a much more difficult reading task for the haptic reader by creating a greater area to be inspected and the concomittant problem of integrating information from different parts of the display. For example, some commercially produced wall maps and globes for the blind are several feet in diameter. Typically, when graphic displays are made for a blind person much of the "unessential" symbology is eliminated in order to reduce the display to a manageable size. While there have been no major attempts to investigate empirically the effect of the size of a display on its readability, it has been suggested (Wiedel and Groves, 1969) that tangible displays be kept within hand span for the haptic reader.

To date there are no rules of thumb and only a limited amount of information available to guide the designers of haptic displays as to the size and nature of the symbols to be used on displays. It is obvious that there are physical limitations as to how small a given symbol or figure can be reduced and remain discriminable. However, at our current state of knowledge there isn't any way of determining how small a symbol could be made because the recognition threshold for a symbol will vary as a function of the configuration of the symbol or the elements contained within it.

In constructing tangible graphic displays judgments have to be made concerning the size of elements to be placed on the display. If the elements are too small they become unrecognizable or if elements are to be judged on the basis of differences in size then differences that are too small result in nondiscriminable symbols. In visual displays the reader can alter the angualr size of the elements of the display by moving the display closer to the eyes and thereby increasing the apparent size. Tactually, no such adjustments are possible and the absolute size of the elements is critical. Technically, the producers of tactile graphic displays not only need sets of empirically derived highly discriminable symbols but also sets of values that indicate the discriminability along different physical dimensions. For example, Berla' and Murr (1975) empirically derived a set of values for the tacutal discrimination of line width using the method of constant stimuli in a psychophysical experiment with blind children. The outcome of their experiment generated a set of values which could be used to determine mathematically the smallest differences between the width of two lines that were discriminable 90% of the time by blind children.

The relationship between figure and ground is an important aspect in designing tangible displays. For example, it is common practice among designers of tactile displays to use texture in a way that is analagous to the use of color on inkprint maps. Color is often used to differentiate adjacent areas from one another as well as to enhance the contrast between figure and ground. Berla' and Murr (1975) compared the performance of blind children reading a tactile pseudomap which contained background textures with a group of blind children reading the same pseudomap without textures. Both groups of blind children were asked to perform two tasks, namely, locating a series of identical point symbols on the map and tracking a line with their fingertips from a starting point to a goal.

The use of the textures on one pseudomap significantly degraded performance. Blind students located 20% fewer symbols and took 36% more time on the map containing the textures than on the map without the textures. It also took students 41% longer to track the line on the map with the textures than it did on the map without textures. This study showed that the addition of texture to a map made it more difficult to detect tactual figures from background. Unlike color, it did not enhance performance but actually degraded it.

Discriminable Symbols

Because there is a lack of an extensive body of research on basic tactual perception with blind children, attempts have been made to identify sets of tactually discriminable symbols.

A few researchers have worked with geometric forms attempting to determine which geometric forms are most tactually discriminable (Degowin and Dimmick, 1928; Austin and Sleight, 1952). By far the circle has been reported as the most discriminable of all tactual figures. This is due to the fact that researchers have used the circle in combination with other geometric forms which have corners or angles. As such the discriminability of any tactual symbol depends upon the other forms within a series so that a circle becomes very much less discriminable when the other members of the series are ellipses. Therefore, the research reporting on discriminable symbols is not generalizable beyond the set of stimuli within a given series.

In addition to geometric forms a few studies have been reported on the discriminability and identification of letters (Dinnerstein and Wolfe, 1962; Austin and Sleight, 1952; and Schiff, 1966). These studies have used capital letters which varied in size, height, and type style. However, these stgudies have been fairly consistent in showing that most capital letters have been found to be highly discriminable by haptic readers. In addition, research with the Optacon, (an electronic device that converts printed letters to a vibrotactile display) has shown that very young blind children can learn to identify all capital letters in a very brief period of time. Consequently, it appears that with a minimum amount of training blind children could easily learn to

identify all 26 raised capital letters which could then be used as symbols on tangible graphic displays.

In addition to geometric forms and alpha-numeric figures, attempts have been made to identify those ink print symbols that are also tactually discriminable when made tangible. Three general classes of symbols are needed to construct graphic displays for the blind; namely, area, point, and linear symbols. Nolan and Morris (1971) have done the most extensive series of studies on the discriminability of inkprint symbols and have identified a small set of symbols in each of the three classes mentioned that are highly discriminable by blind children.

## Exploring and Reading Graphic Displays

The tactual perceptual process, by its very nature, is serial and fragmentary (Lashley, 1951; Revesz, 1950). Unlike vision, it is not possible to obtain a total perception of a stimulus in one perceptual act. The haptic observer must explore the stimulus in successive movements, analyzing each separate precept and integrating it with previous precepts. Concequently, haptic exploration is an exceedingly slow and fragmentary process as compared to vision. Relative to the other sense organs the hand is the only perceptual system where the freely roaming fingertips determine the order in which critical information (distinctive features) is sequenced for processing by the brain. In the visual system, within a single fixation, there is a simultaneous perception of the distinctive features and their spatial relationships which are invariant. For audition, the serial temporal order of the stimulus events is fixed. By way of analogy, the critical information in a melody is the temporal sequence of the notes. If the sequence

of the notes is altered either by changing the temporal pattern (the time value given to each note) or the arrangement of the notes within the tune, a new melody is created. In essence, the nature of the emergent pattern (the melody) is a function of the principle of serial order (Lashley, 1951). However, for the freely roaming hand, the serial order of the distinctive features is subject to wide variation depending upon the consistency of the system that is used in inspecting tactile stimuli. For example, if a shape had six distinctive features a blind child could feel the distinctive features in any one of a possible 720 different sequences (Berla', Butterfield and Murr, 1976). In reality, there are other factors such as the position of the stimulus with respect to the observer and the habitual ways of responding which would substantially reduce the number of possible alternatives. However, the fact is that if the same identical stimulus is presented to the same child on two or more occasions, variations in inspection strategies will alter the sequence of the distinctive features and thus may determine whether the child perceives the two stimulus events as being identical or different.

It might be assumed that observing blind children performing tactually would provide the researcher with a sophisticated model of the development of haptic skills. This assumption might be based on the belief that blind children, out of necessity, depend more heavily on haptic skills to

acquire information or because of the emphasis in their education on learning specific haptic skills, most notably braille. However, this assumption, for the most part, would be in error. Research on the haptic skills of blind children in grades one through twelve has generally indicated that their haptic skills are extremely poor (Nolan and Morris, 1971). For example, on haptic map reading tasks blind children characteristically fail to define and explore the extent of the area (map) they have been asked to examine, are very unsystematic when instructed to explore a tangible display, exhibit poor tracing skills, and poor shape discrimination skills (Berla', Butterifeld and Murr, 1976; Berla' and Butterifeld, 1977; Nolan and Morris, 1971). Furthermore, the lack of these skills permeates all grade levels and the orderly progression of increasing ability with years in school seems to be more the exception rather than the rule.

In an attempt to delineate the problems and potential skills needed by blind children to discriminate shapes and read tangible political maps, a videomatic behavioral analysis was undertaken to examine the behaviors of good and poor haptic map readers (Berla', Butterfield and Murr, 1976). Thirty-six blind students in grades four through twelve were videotaped as they attempted to locate specific shapes (U.S. states) on a

pseudopolitical map. On the basis of error and time scores the videotapes of the nine best and the nine poorest map readers were analyzed in order to identify specific behaviors which differentiated the good map readers from the poor map readers. The good map readers were much more systematic and complete in their exploration of shapes than the poor map readers. Using their index fingers the good map readers faithfully traced the outline of a shape, stopping at various points to carefully inspect a distinctive feature. (Distinctive features were defined as the degree or preseveration on specific features as determined by two judges). The good map readers appeared to be able to locate and identify a particular shape on the map on the basis of two or three distinctive features. Poor map readers were generally unsystematic and incomplete in their exploration of a shape. They had difficulty tracing the outlines of the shapes and paid little attention to the distinctive features of a given shape.

In two subsequent studies (Berla' and Butterfield, 1977), blind students were trained to examine shapes by first locating a reference point on a shape, then by tracing the contour of the shape in a clockwise or counter-clockwise motion and finally by returning to the reference point. The students were then asked to retrace the shape in the same way but to pick out the parts of the shapes which were different (distinctive features) and remember them. On a subsequent shape recognition

task the students were given a shape for examination which was then removed and replaced by four choice figures from which they had to choose the correct shape. The students trained to examine the shapes systematically significantly outperformed a matched untrained group on the same task. On another task two equivalent groups of blind students were asked to locate shapes on a political map. One group received the training described above with the instruction to locate a target shape on the map by searching for its distinctive features. The trained students again significantly outperformed an equivalent untrained group. It should be noted that training in each of the previously reported studies was less than one and one-half hours per child, yet it resulted in a 20% to 40% gain in accuracy and speed of performance.

## Summary and Conclusions

It is apparent from the preceding review that the state of the art leaves much to be done. While there is a small body of knowledge with respect to the design of graphics, the skills necessary for reading them, and the knowledge the reader needs to bring to the task, very little of this information has been incorporated into the production of graphics commercially or into the curriculum for blind children in the United States.

While there are a number of problems to be solved and many steps that must be taken to remediate the situation, it is apparent to ~~this writer~~ me that little will be accomplished unless major thrusts are made simultaneously The first priority has to be the use of more sophisticated technology in making tangible displays for the blind on a commercial basis. There is sufficient information available today that would enable producers of graphic displays to make displays that are substantially more legible than those currently being produced in the United States. Among other things, guidelines for the design of tangible displays need to be delineated and standardized so that the decisions regarding the symbology and their plaement on a tangible display are not left to individuals who have neither a knowledge of tactual perception nor training in the area of the blind. Without this intitial thrust all the research and training in perception, reading skills and concept development will not make an illegible and poorly designed graphic~~s~~ readable by even the most sophisticated haptic reader.

With respect to research, one of the most fruitful areas would appear to be the area of perceptual-motor skills training. The few studies that have been done in this area have demonstrated substantial improvement in performance with only short periods of instruction. This area needs to be given more attention by researchers than has been done up to this time. This is not to say that important and meaningful research cannot be conducted on symbology, design and concept development which are certainly in need of continued efforts.

Since tangible displays involve independently researchable but interrelated problems, any development or improvement in one area will affect the nature and outcome of research in other areas. For example, innovations in production technology would greatly improve the legibiltiy of graphic displays which, in turn, might increase the frequency with which teachers incorporate tangible displays into their curriculum which, in turn, might affect the development of children's skills and concepts. The most important thing, however, is to implement whatever information and techniques that have been developed into the educational system.

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